Ground-based Electro-Optical Deep Space Surveillance System (GEODSS) Past & Future Improvements

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GEODSS Missions

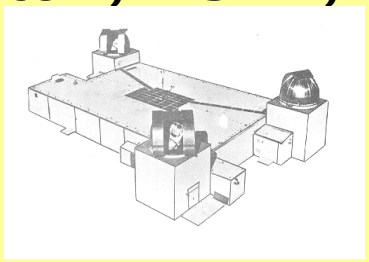
- To provide timely astrometric data on tasked deep space objects (active payloads, debris, and maneuvered and “lost” objects) in support of AFSPC space surveillance mission
  - Deep Space: objects with mean motion less than or equal to 600 arc/sec per second
  - System reports azimuth and elevation of objects
    - “Angles Only”
- To provide timely photometric data on tasked deep space objects in support of USSPACECOM space surveillance mission
  - Space Object Identification (SOI) capability detects, samples, and records object brightness data at 1 kHz
  - System reports data to Combined Intelligence Center (CIC) smoothed to 100 Hz rate

Sensors

- Telescope: f/2.15, 2.1º FOV
- Telescope Effective Aperture -- 0.46 m^2 (1 m diameter)
- Passive electro-optical sensor
  - Ebsicon (electron-bombarded silicon) vacuum tubes, 80 mm focal plane circular diameter
    - Sidereal and Rate Track: For Track and Search
    - IFOV in ‘zoom’ mode: 4.5 arc sec
    - Also used to maintain SOI closed loop tracking
  - Photo-Multiplier Tube: SOI

System Diagram

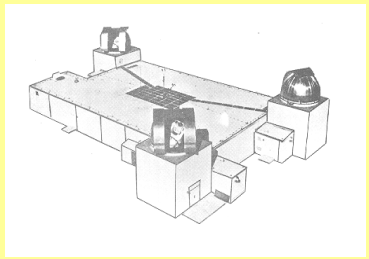
Site 1, WSMR, NM



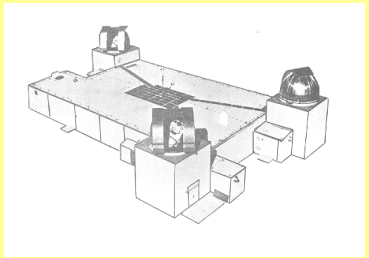
CMAS

OC³F

Site 2, Diego Garcia, BIOT



Site 3, Maui, HI



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GEODSS History

- Original GEODSS system fielded in early 80s
- Site in Korea closed in 1994
- GEODSS Modification Program (GMP) operational in the Summer of 1999
  - Introduced the Optical Command, Control and Communications Facility (OC^3F) at Edwards AFB, CA
- GMP included GEODSS Technology Insertion Program (GTIP)
- GTIP introduced new Sensor Controller in which accuracy improvements were achieved
- About 3 years prior to GMP, GEODSS metric accuracy deteriorated
  - Reason yet to be absolutely identified

Tracking Methods

- Sidereal Track
  - Star field held steady on image plane
  - Objects ‘streak’ maintaining streak end-points within FOV
    - Each streak is boresighted on 1.05° zoomed image
    - Exposure: 0.3 or 0.6 s
  - 12 to 15 images against a star field, each contains a streak, forms a composite streak image, from which an ‘obs’ (observation) is generated
  - Three metric obs form a ‘tracklet’
- Rate Track
  - The object is boresighted and held steady on the image plane -- stars form streaks
    - Exposure: 0.3, 0.5, or 1.0 s

Pointing Angles

- Modular Precision Angular Control System (MPACS) controls the mount and telescope pointing
- Mount is configured with Inductosyn Angular Encoders
  - Pointing accuracy: 1.5 arc sec
  - Encoder resolution: 0.62 arc sec
- All angles are developed solely from the mount angular encoders
- Mount Model iteratively locates and centroids 54 stars
  - Least squares fit
  - Stars uniformly distributed over field-of-regard
- Present: There are NO in-frame metrics

Improvements to GMP versus Legacy GEODSS

- Mount model incorporated least squares fit
  - Vs. Kalman filter
- Rigorous treatment of coordinate systems
- Improved plate model
- Two 3 obs tracks separated in true anomaly
  - Vs. 5 obs track performed contiguously
- Streak detection algorithm incorporated Max value projection
  - Vs. Kalman filter
  - Post Max Value a cluster/moment algorithm is used
- Treatment of Annular Aberration
  - In GEODSS post GMP as well as legacy

Star Catalogs in Use

- Smithsonian Astrophysical Observatory (SAO) Catalog
- Astrographic Catalog Reference Stars (ACRS)
- Hubble Guide Star Photometric Catalog

Calibration of Observational Data

Reference orbits generated by NASA's Crustal Dynamics Data Information System

- **Calibration Satellites (CalSats)**
  - **Lageos 1: SATNO 08820**
  - **Lageos 2: SATNO 22195**
  - **Etalon 1: SATNO 19751**
  - **Etalon 2: SATNO 20026**
  - **GPS sats 34, 35, & 36: SATNOs 22779, 22877, & 23027**
- **Cals use two weeks of obs calculating residuals against reference orbits**
- **Consideration/treatment of annual aberration change?**

Deep STARE Metric Improvements

Deep-space Surveillance Technology Advancement and Replacement for Ebsicons (Deep STARE)

- **Incorporation of CCDs: 1960 x 2560 monolithic array**
  - **IFOV: 2.3 arc-sec pixels -- 24 μm pixel pitch**
- **Improvements in accuracy projected for:**
  - **Mount model**
  - **Enhanced streak detection algorithms**
  - **Observations via incorporation of in-frame metrics**
  - **More robust plate model**
- **Further separation of obs in true anomaly**

Changes to the present star catalog will have some, but minimal impact on improving metric accuracy.

Deep STARE SOI Improvements

Deep STARE SOI

- 32 x 32 CCD array for SOI, 24 μm pitch pixels
- Array located on telescope focal plane
- SOI AND Closed loop tracking achieved on one array
  - Improved signal strength
- CCD $Q_e \cong 0.70$ vs. PMT $Q_e \cong 0.10$
  - Improved sensitivity

- Continuing implementation of instrument calibration & atmospheric extinction estimation

SOI presents greatest need for improved star catalog

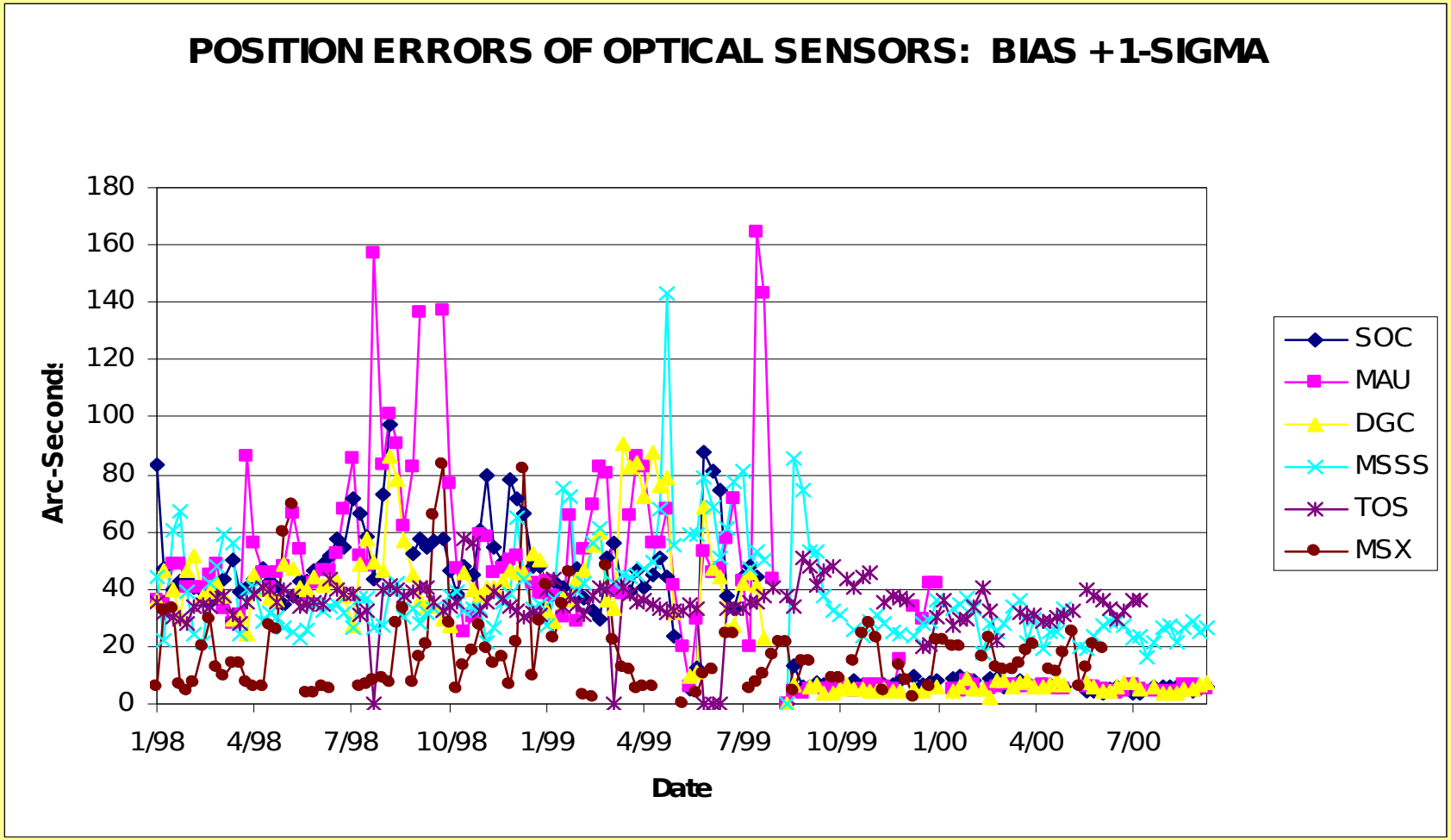
Star Catalog Needs

- **Astrometric catalog needs**
  - **Metric Accuracy: ≤ 0.3 arc-sec**
  - **Brightness and color: 12 to 15 m_v color corrected for the CCD**
  - **Density: 5 to 10 stars/square degree**

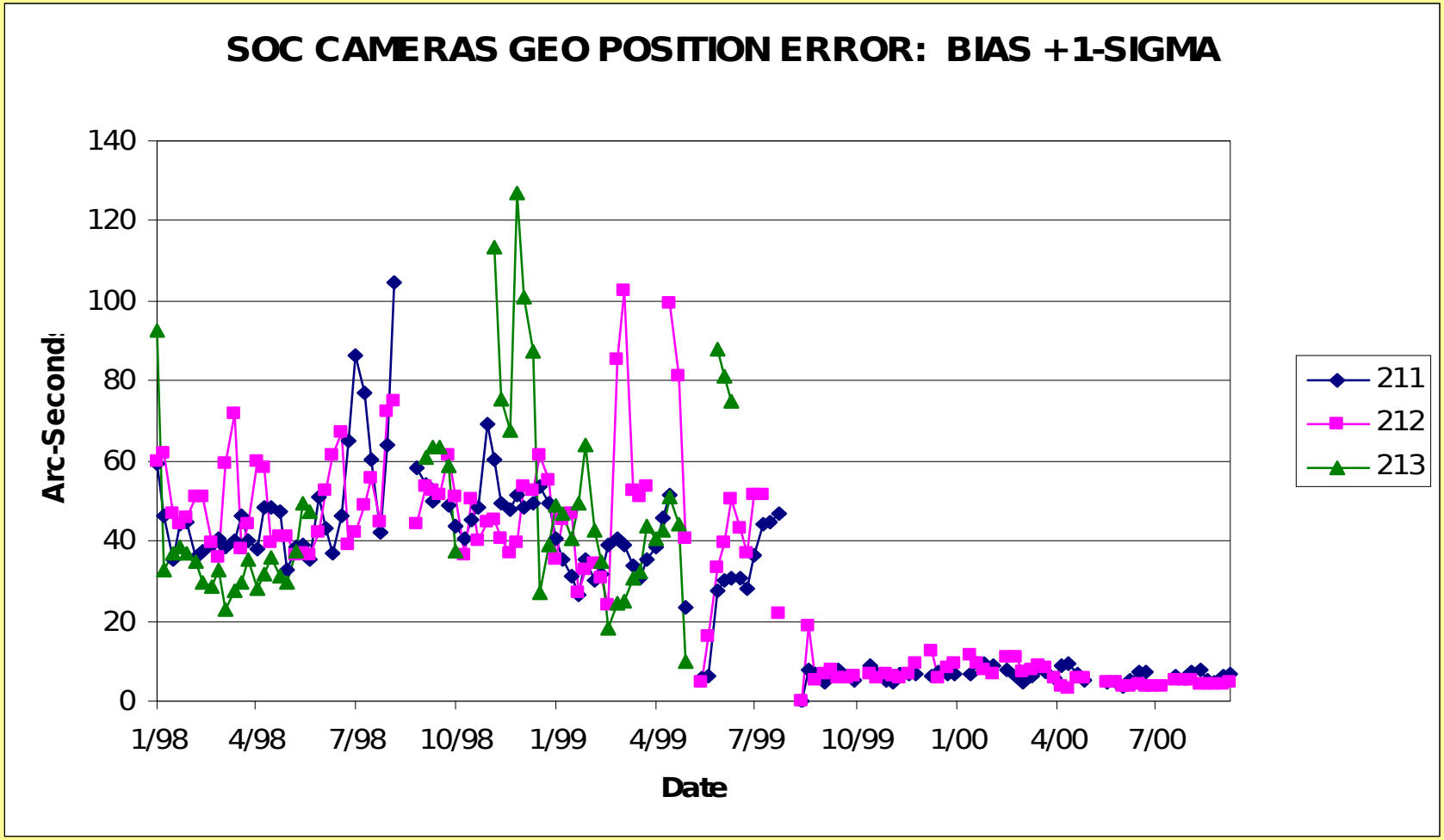
- **Photometric catalog needs**
  - **Photometric accuracy: ≤ 0.05 m_v**
  - **Brightness: 9 to 12 m_v color corrected for the CCD**
  - **Density: ~1000 single stars**

All stars isolated, uniformly distributed & located outside of the galactic plane

Passive Optical Sensor Data



GEODSS Site 1 Data: Historical Perspective



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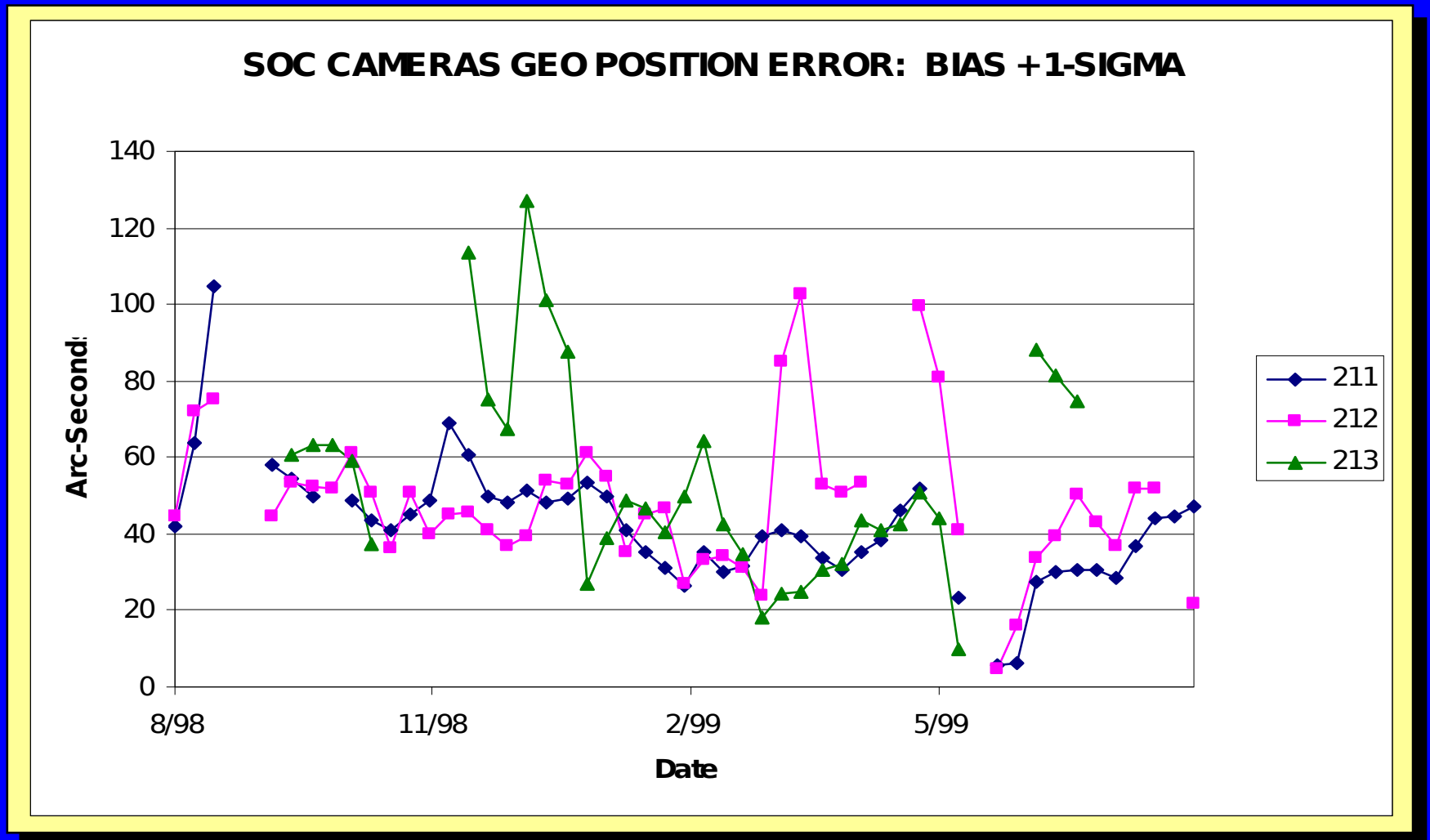
GEODSS Site 1: System Representative Data, Pre GMP



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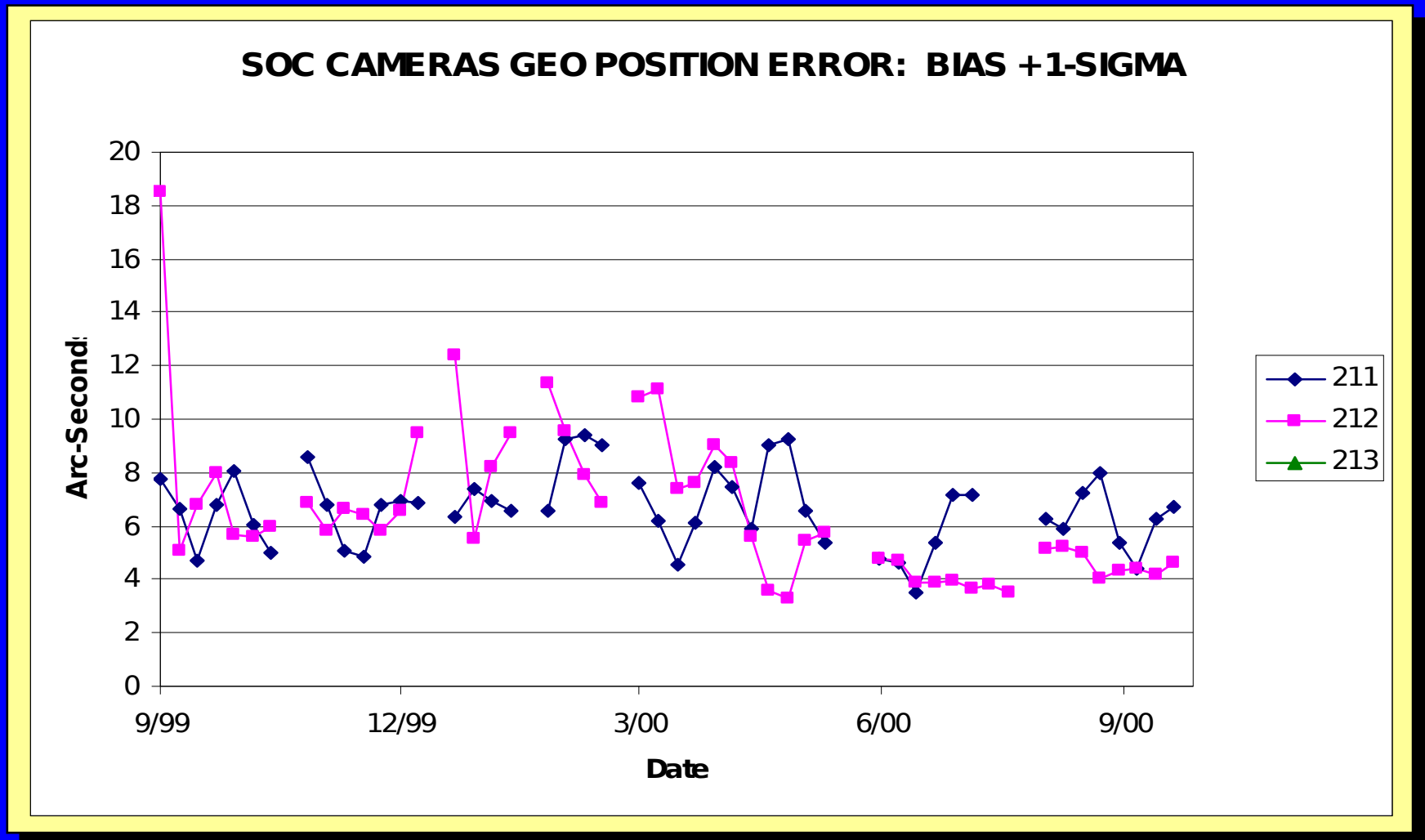
GEODSS Site 1: System Representative Data, Post GMP



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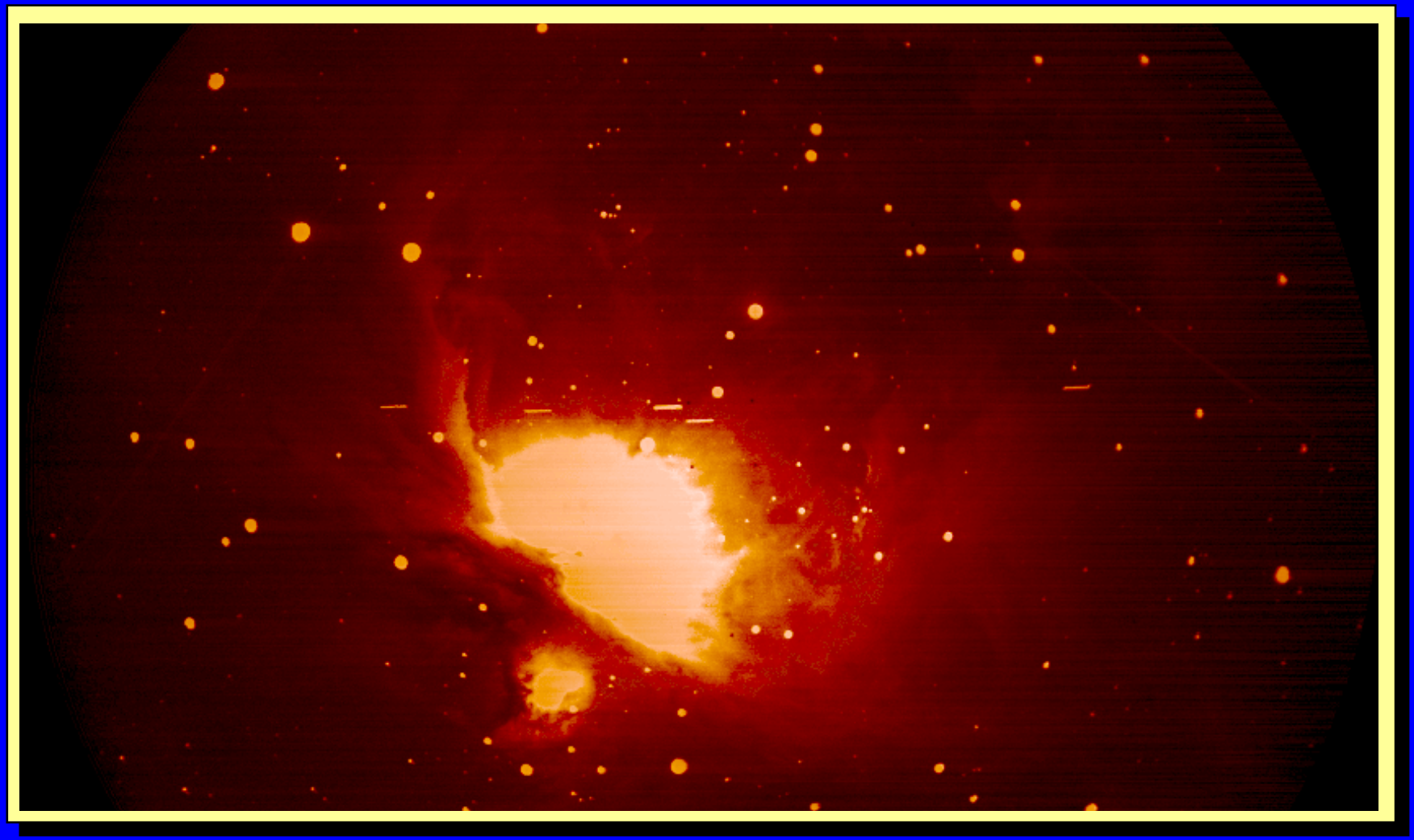
Orion Nebula (M42)



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